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The possibility of enhancing some properties of self-compacting concrete by adding waste plastic fibers

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ABSTRACT

An attempt was carried out to develop some properties of self-compacted concrete (SCC) by adding waste plastic fibers (WPF) resulting from cutting beverage bottles. Many tests were conducted to investigate the effect of adding WPF on the fresh properties, whereas other tests were applied on that kind of concrete to study the effect of this type of waste on hardened properties. For this reason, different self-compacting concrete mixtures were designed at constant water-to-binder ratio of 0.35 and 490 kg/m^3 of binder content. The class F fly ash was replaced with cement as 25% by weight. The eighth designated plastic fiber contents of 0%, 0.25%, 0.5%, 0.75%, 1%, 1.25%, 1.5%, 1.75% and 2% by volume. The workability properties of self-compacting concrete mixtures were performed to slump flow diameter, T_{50} slump flow simultaneously, V-funnel flow at the same time, and L-box height ratio. The 7, 14 and 28-day compressive strengths of self-compacting concretes were also measured. Moreover, the 7, 14 and 28-day flexural strengths of concretes were also measured. The test results showed that the plastic fibers have adverse effect on the fresh properties of self-compacting concrete and improvement by hardened properties.

1. Introduction

Over the last decades, huge quantities of non-degradable waste, especially in the form of waste plastics (WP) have proved that they have serious challenges to the environment; moreover they are considered as one of the most dangerous sources of pollution [1–6]. The reuse of plastic wastes plays an important role in sustainable solid waste management. Plastic waste management helps to save natural resources that cannot be replenished, decreases pollution of the environment and also helps to save and recycle energy production processes [7].

Self-compacting concrete SCC is a concrete that can flow and infiltrate under its own weight, and pass through the spaces between the reinforcement bars to fill the framework completely. It simultaneously maintains its stable composition [8–10]. It is a kind of concrete with excellent deformability and segregation resistance [11]. The hardened SCC is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete [12]. SCC consists basically of the same constituents as a normally vibrated concrete. However, there is a clear difference in the concrete composition. SCC requires a higher proportion of ultra-fine materials and the incorporation of chemical admixtures, particularly an effective high range water reducer [13].

Fiber-reinforced concrete (FRC) is a composite material made primarily from hydraulic cements, aggregates, and discrete reinforcing fibers [14]. The effects of adding many types of fibers on self-compacted concrete were investigated by many scientists and researchers [15].

FRC and fiber reinforced cement composites (FRCCs) are widely used in civil infrastructures including airports, highways, industrial floors, bridge decks, elevated slabs, overlays, tunnel linings, and precast elements [16–20], due to their higher load carrying capacity and crack resistance.

Many researches dealt with the effects of adding different types of fibers on the properties of SCC [21–24].

Application of plastic waste to mortar and concrete is very common and a number of studies have been conducted to evaluate the performance characteristic of the plastic concrete. Choi et al. [25] conducted experimental study to investigate the effect of plastic waste (PET bottles) as aggregate on properties of concrete.

Many attempts were done to benefit from the waste plastic as aggregate particles for the purpose of developing concrete or mortars properties or study effects of these kind of additives on the behavior of concrete [26–28]. Batayneh et al. [29] used plastic waste as partial replacement of sand in concrete. The result showed that 20% substitution of sand can reduce compressive strength up to 70% as compared to normal concrete. Many studies [30–33] also used a consumed plastic bottle for sand substitution

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within composite materials for building application. Brahim Safi et al. [34] used plastic waste from 0 to 50% for sand substitution in self compacting rubberized mortar and investigated the effect on physical and mechanical properties. The results of mechanical test showed that, the compressive strength at 28 days of self-compacting mortar containing up to 50% of plastic waste was acceptable for lightweight mortars with the bulk density 1.5 kg/m^3. Researchers [35,36] have also studied the use of consumed plastic bottle waste as sand-substitution aggregate within composite materials for building applications. The studies of these researchers showed that the density and compressive strength were decreased when the PET aggregates exceeded 50% by volume of sand. Also, it was found that the addition of plastic waste ($<$ 10%) in volume inside of a cementitious matrix does not imply a significant variation of the concrete mechanical features.

WP had been used as waste plastic fibers (WPF) in concrete or mortars in many studies [37,38]. Al-Hadithi [39] studied the use of plastic bottle waste with different percentages of concrete volumes. These percentages were 0.5%, 1% and 1.5%. Results proved that the addition of waste plastic fibers with these percentages lead to improvements in compressive strength and splitting tensile strength of concretes containing plastic fibers, but the improvement in splitting tensile strength appeared more clearly.

Pandyaet al. [40] evaluates the mechanical properties of PET fiber reinforced concrete using micro fine material with particle size much finer than other cementitious materials called Alccofine as admixture. The PET fiber are used with 0%, 0.5%, 1.5% and 3% by weight of cement with Alccofine (GGBS) percentage of 0%, 3%, 6% and 9% replacing cement for M30 grade concrete. Results showed that:

- Workability of concrete is decreased with increased in fiber content. Maximum workability is achieved with 0% PET fiber and 9% Alccofine.
- Compression test results: It can be clearly seen that with increase in fiber content, compressive strength increases up to V_f=1. 5% while compressive strength decreases. Compressive strength increases with increase in Alccofine up to 6% which then decreases. Maximum compressive strength is achieved with 1.5% PET fiber and 6% Alccofine.
- Flexure strength increases with increases in both PET fiber and alkaline. Maximum flexural strength is achieved with 1.5% fiber and 9% Alccofine.
- PET fiber 0.5% and Alccofine 6% gives maximum compressive strength which is 22.65% more in comparison with control mix. This comes at a cost increase of only 3.84%.
- PET fiber 1.5% and Alccofine 9% gives maximum flexure strength which is 52% more in comparison with control mix. And for this strength there is a cost increase of only 5.75%.

In this research an attempt is made to benefit from the WP of PET bottles by cutting these kinds of materials to fibers, which are then used in the SCC transforming them to a concrete sustainable material. The addition of WPF helps to convert brittle concretes into more ductile ones. The main role of WPF fibers is to transfer stress across the crack and thus to restrain crack opening and propagation. But there is a negative effect of this type of adding on the fresh properties of concrete mixtures represented by decreased in the workability. Combining both WPF and SCC into one type of cement composite would opining new possibilities in sustainable engineering and structural engineering.

2. Experimental program

2.1. Materials

2.1.1. Cement and fly ash

Ordinary Portland cement (CEM I 42.5R) with specific gravity of 3.15 g/cm^3 and Blaine fineness of 326 m^2/kg was utilized in this study. Class F fly ash (FA) according to ASTM C 618 [41] with a specific gravity of 2.25 g/cm^3 and Blaine fineness of 379 m^2/kg was utilized in the manufacturing of the SCCs. Physical properties and chemical compositions of the cement and fly ash are presented in Table 1.

2.1.2. Aggregates

The coarse aggregate was river gravel with a nominal maximum size of 16 mm and the fine aggregate natural river sand, was used with a maximum size of 4 mm. River sand, and river gravel had specific gravities of 2.65, and 2.71, respectively. The particle size gradation obtained through the sieve analysis of the fine and coarse aggregates are given in Fig. 1.

2.1.3. Superplasticizer

A Polycarboxylic ether type of superplasticizer (SP), which acts by steric hindrance effect [42], with specific gravity of 1.07, was employed to achieve the desired workability in all concrete mixtures. The properties of superplasticizer are given in Table 2 as reported by the local supplier.

2.1.4. Waste plastic fiber

Rectangular shape of waste plastic fiber with dimension (10×2 mm^2) and thickness of (0.3) mm made from polyethylene terephthalate (PET) was used in this research. The waste fibers were produced by cutting plastic beverage bottles by hand as seen in Fig. 2. The specific gravity of these fibers was 1.12.

2.1.5. Mixing water

Ordinary tap water is used in this work for all concrete mixes and curing of specimens.

2.2. Mixture design

Self-compacting waste plastic fibers concrete (SCWPC) mixtures were designed having a constant w/b ratio of 0.35 and total binder content of 490 kg/m^3. The class F fly ash was used as a 25% of total binder content in all mixtures. Totally 9 different SCRC mixtures were designed regarding to above variables, the first SCRC mixture was reference mix, which was not containing WPF. The detailed mix proportions for SCRCs are presented in Table 3. The concrete mixtures were designed according to slump flow

Table 1
Physical properties and chemical compositions of Portland cement and fly ash.

Analysis report (%)	Cement	Fly ash
CaO	62.58	4.24
SiO_2	20.25	56.2
Al_2O_3	5.31	20.17
Fe_2O_3	4.04	6.69
MgO	2.82	1.92
SO_3	2.73	0.49
K_2O	0.92	1.89
Na_2O	0.22	0.58
Loss on ignition	3.02	1.78
Specific gravity	3.15	2.25
Blaine fineness (m^2/kg)	326	379

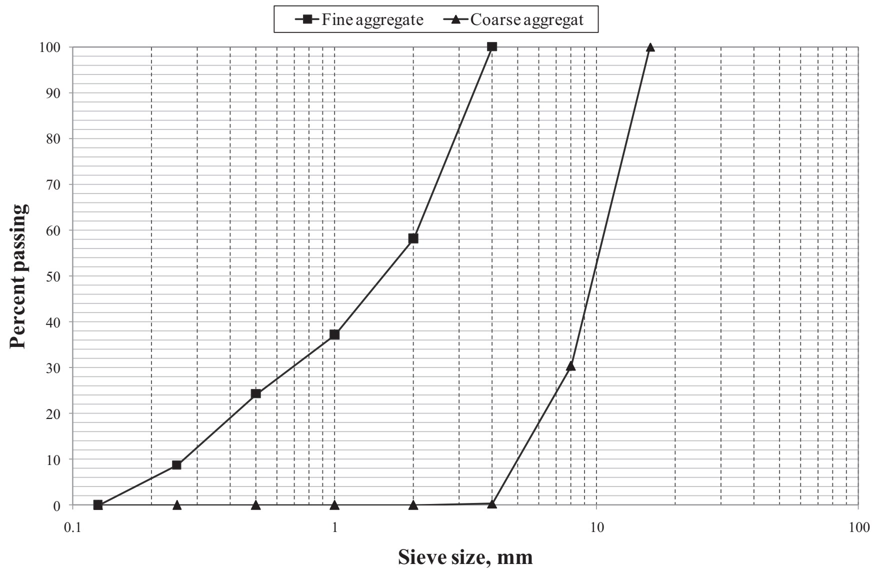

Fig. 1. Sieve analysis of fine and coarse aggregat.

Table 2
Properties of superplasticizer.

Properties	Superplasticizer
Name	Glenium 51
Color tone	Dark brown
State	Liquid
Specific gravity (kg/ l)	1.07
Chemical description	Modified Polycarboxylic type polymer
Recommended dosage	%1–2 (% binder content)

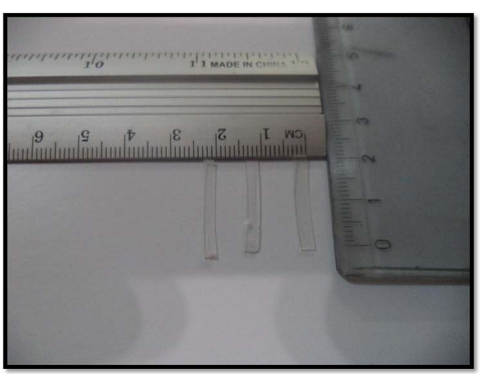

Fig. 2. Waste plastic fibers.

diameter of 700 ± 50 mm which was achieved by using the superplasticizer at varying amounts.

2.3. Concrete casting

To achieve the same homogeneity and uniformity in all SCRC mixtures, the batching and mixing procedure proposed by Khayat et al. [43] was followed since the mixing sequence and duration are very vital in the self-compacting concrete production. According to this mixing procedure, the plastic fiber, fine and coarse aggregates in a power-driven revolving pan mixer were mixed homogeneously for 30 s, and then about half of the mixing water was added into the mixer and it was allowed to continue the mixing for one more minute. After that, plastic waste and aggregates were left to absorb the water in the mixer for 1 min. Thereafter, the cement and fly ash was added to the mixture for mixing another minute. Finally, the SP with remaining water was poured into mixer, and the concrete was mixed for 3 min and then left for a 2 min rest. At the end, to complete the production, the concrete was mixed for additional 2 min. The workability and passing ability of the mixtures were tested by means of different tests. Moreover, three 150-mm cubes were taken to measure the compressive strength of self-compacting concretes and three 100*100*500 prisms were taken to measure the flexural strength. Following the concrete casting, specimens were wrapped with plastic sheet and left in the casting room for 24 h at 20 ± 2 °C and then they were demoulded and tested after 7and 28-days water.

2.4. Test procedure

The recommendations in EFNARC [44] committee (European Federation for Specialist Construction Chemicals and Concrete

Table 3
Mix proportions for self-compacting concrete (kg/m^3).

Mix ID	Cement (kg)	Fly ash (kg)	Sand (kg)	Gravel (kg)	Crush sand (kg)	Water (kg)	SP (kg)	WPF (%by volume)
F0	392	98	615.83	878.64	264.3	137.28	2.80	0
F0.25	391	97.75	613.87	875.84	263.534	136.85	3.2	0.25
F0.5	390	97.5	612.3	873.6	262.86	136.5	3.75	0.50
F0.75	389.06	97.25	610.82	87.49	262.22	136.17	4	0.75
F1.0	388.08	97.02	609.28	869.12	261.56	135.82	4.25	1.00
F1.25	387.1	97.75	607.75	867.104	260.90	135.48	4.5	1.25
F1.5	386.12	96.53	606.20	864.90	260.40	135.14	5	1.50
F1.75	385.14	96.285	604.66	862.71	259.58	134.79	5.25	1.75
F2.0	384.16	96.04	603.13	860.51	258.92	134.425	5.80	2.00

Systems) were followed to carry out the slump flow diameter, T_{50} slump flow time, V-funnel flow time, and L-box height ratio. Slump flow value, which is used for the description of the fluidity of a fresh concrete in unconfined conditions, is a sensitive test. It is the primary check for the fresh concrete consistence to meet the specification. Thus, it can normally be specified for all self-compacting concretes. Moreover, additional information about segregation resistance and uniformity of concrete can be achieved from the visual observations during the test and/or measurement of the T_{50} time that is the measured time for flowing of concrete to a diameter of 500 mm [44].

Both the T_{50} slump flow time and V-funnel flow time can be used to measure the viscosity of the self-compacting concrete. The direct viscosity cannot be achieved by these tests but the results of these tests describe the rate of flow which is related to the viscosity. V-shaped funnel is used to measure the V-funnel flow time, it is filled with fresh concrete and then it is allowed to flow out from the funnel, the elapsed time of fully flowing is recorded as the V-funnel flow time.

The passing ability of the fresh concrete mix to flow through confined spaces and narrow opening such as areas of congested reinforcement without segregation, loss of uniformity or causing blocking can be measured in terms of L-box test. A measured volume of fresh concrete is allowed to flow horizontally through the gaps between vertical, smooth reinforcing bars and the height of the concrete beyond the reinforcement is measured.

Wet density test was performed on 150 mm cubes in accordance with the standards ASTM C 642, 2006 [45]. The results for wet density of self-compacting concrete were given as the average of three samples.

Ultrasonic pulse velocity test was performed on 150 mm cubes in accordance with the standards (ASTM C 597, 2009) [46]. Pulse velocity was determined by dividing the pulse time to length of path as shown in the following equation. The results for ultrasonic pulse velocity of self-compacting concrete were given as the average of three samples.

$$\boldsymbol{V} = l/t$$

where: V = Velocity (km/sec), l = length of path (km) and t = time (seconds).

Compression test of self-compacting concrete sample was carried out with respect to ASTM C39 [47]. The results for compressive strength of self-compacting concrete were given as the average of three samples.

Flexural strength test of self-compacting concrete sample was carried out with respect to ASTM C78 [48]. The results for flexural strength of self-compacting concrete were given as the average of three samples.

3. Results and discussion

3.1. Fresh concrete properties

The results of fresh concrete tests are shown in Table 4. These tests included slump flow.

Diameter, T_{50}slump flow time, V-funnel flow time, L-Box ratio test and Wet density. It can be noticed from this table that, the slump flow diameters of all mixtures were in the range of 650–780 mm, the T_{50} slump flow times were in the range of 3–12 s. The V-funnel flow times were in the range of 9–25 s, whereas the L-box ratio was in the range of 1–0.75. Test apparatus sketching has been given in Fig. 3. Wet density value varied from 2340 kg/m^3 to 2235 kg/m^3.

Table 4
Fresh properties and wet density of all mixes of SCC.

Mix ID	Slump flow mm	T_{50} Slump flow time (sec)	V-funnel time (sec)	L-box ratio	Wet density Kg/m^3
F0	780	3	9	1.00	2340
F0.25	760	5	11	0.95	2320
F0.5	750	6	13	0.90	2315
F0.75	740	7.5	14	0.88	2300
F1.0	720	8	16	0.85	2285
F1.25	700	8.5	18	0.82	2270
F1.5	690	9.5	20	0.80	2255
F1.75	670	10	22	0.78	2245
F2.0	650	12	25	0.75	2235
EFNARC	600–750	3.5–6.0	3–15	0.8–1.0	

3.1.1. Slump flow and T_{50} slump flow time tests

There is no doubt that the slump flow test is the simplest and most widely used tests. The straightforward correlation - the higher the slump flow value, the greater its ability to fill formwork under its own weight - makes it very easy to use and interpret the results [49].

Figs. 4 and 5 show the results of slump flow tests and T_{50} Slump Flow Time together. The values of D represent the maximum spread (slump flow final diameter), while the values of T_{50} represent the time required for the concrete flow to reach a circle with 50 cm diameter. Reference mixture (F0) is proportioned at the upper level of self-compatibility, in order to remain within the given limits after the addition of the fibers. The results of the slump flow range between (650–780) mm, the results of T_{50}cm range between 3 and 12 s as shown in Fig. 5. It is very clear from the results that not all of the mixes satisfy the requirements recommended by EFNARC for SCC. None of the mixes show segregation, bleeding or halo-formation. (Fig. 6).

As waste plastic fibers WPF were added, slump flow values generally became lower. The reduction percents in slump flow values were found to increase with the increase in WPF content. These fibers tended to become entangled together and formed clusters at the center of the flow spread which jeopardize the ability of concrete to flow. It can be seen that the flowability is better for low content of WPF than the mixes with high content of WPF. This can be attributed to the high specific surface area for these fibers [50]. The flow time was higher for mixes containing higher WPC content than the mixes with low WPF content since the increase in polymer fibers content leads to increase in the viscosity of the mixes. Mixes with WPF volumetric content equal to or more than V_f=0.75%had T_{50} exceeded the limits of ***EFNARC*** due to the cumulative negative effect for polymer fibers and higher fiber factor.

The effect of adding fibers to conventional concrete leads to more stability and consistency of concrete mix, then reduce the workability. In general, adding fibers reduce the fluidity properties of SCC because of increasing of internal resistance to the fluidity resulting from decreasing in cement paste layer thickness which surrounding aggregate particles, and because of increasing in both plastic viscosity and friction between aggregate and, or friction between aggregate and fibers, also the cross-linked between aggregate and fibers. Slump test is an indicator for the concrete diffusion or evacuation ability [23].

3.1.2. V-funnel time and L-box ratio tests

Results proved that, an increase in WPF leads to an increase in V-funnel time, Slump flow time and L-box ratio because of the above mentioned reasons in Section 3.1.1. As shown in Fig. 7 the lowest V-funnel time was obtained from controlled mixture, and the systematic increasing of V-funnel time witch was observed in WPF content increase.

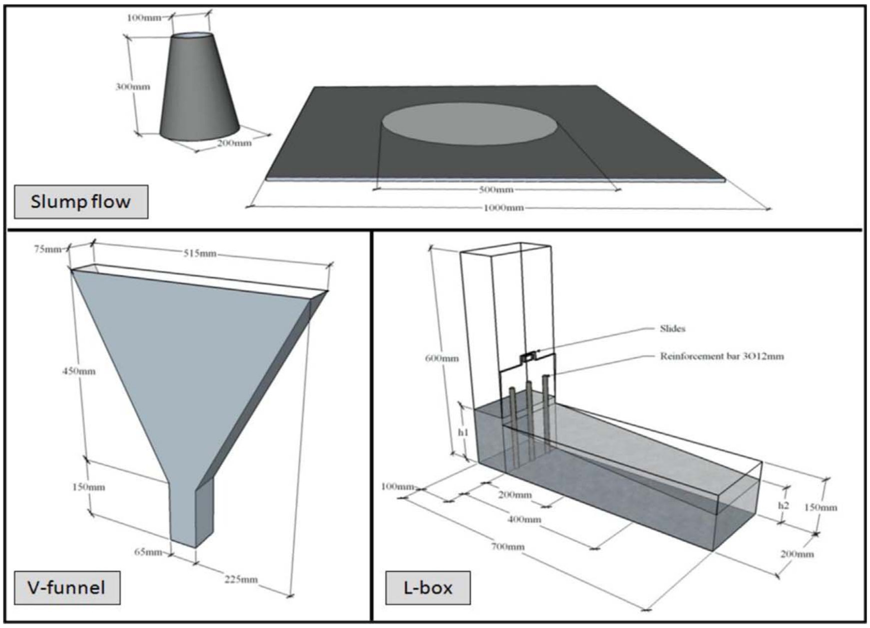

Fig. 3. Sketch of test apparatus used for measuring the fresh state of SCC.

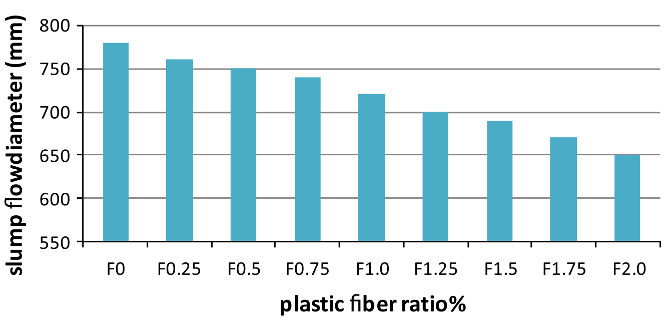

Fig. 4. Slump flow diameter (mm) for all SCCs mixes.

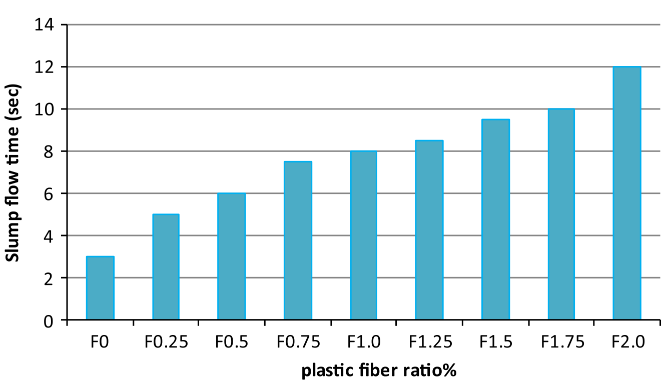

Fig. 5. Time required reaching a circle with 50 cm diameter for all SCCs mixes.

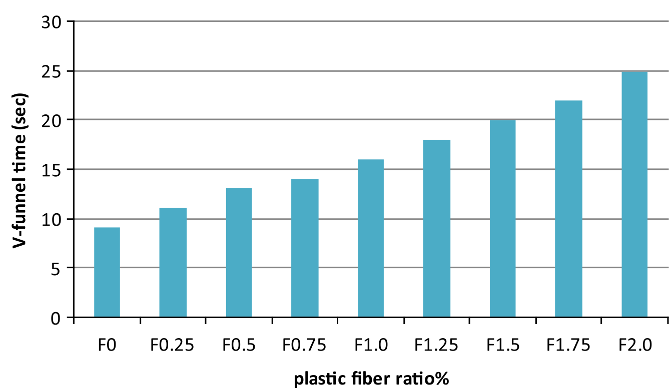

Fig. 6. V-funnel flow time for all SCCs mixes.

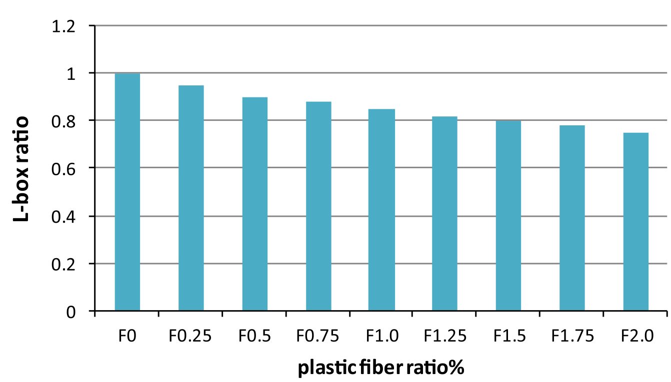

Fig. 7. L-box height ratio for all SCCs mixes.

The L-box height ratio by means of H2/H1 ratio was also determined to specify the passing ability of the produced SCCs. The results obtained from the three bar L-box test which simulates more congested reinforcement [44] are presented in Fig. 7. The L-box height ratio must be equal to or greater than 0.8 to certify that the self-compacting concrete has the passing ability. When the L-box height ratio is 1.0, it shows that perfect fluid behavior of the concrete is obtained [44]. According to Fig. 7, all mixtures satisfy the EFNARC limitation for the given L-box height ratio except two mixtures (F1.75 and F2.0). The L-box height ratio value for the reference mixture (F0) was 1 while it is 0.75 for the mixture with 2% WPF. In addition, increasing the waste plastic fibers WPF resulted in systematical decreasing of L-box height ratio.

3.1.3. Wet density

The Wet density of SCC refers to its mass per unit volume of fresh concrete. It depends on the mixture composition of concrete. Wet density value varied from 2340 kg/m^3 to 2235 kg/m^{3}and is presented in Fig. 8. as waste plastic fibers WPF were added, wet density values of all mixtures generally became lower. The reason

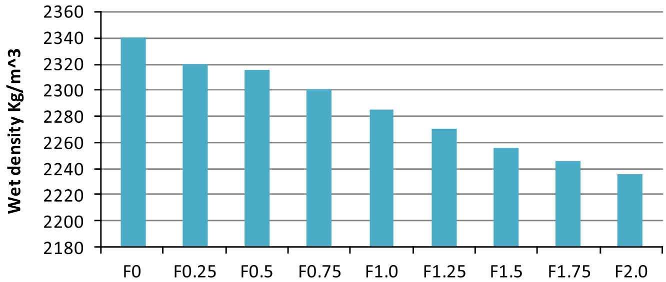

Fig. 8. Wet density for all SCCs mixes.

for this reduction may be attributed to the fact that, the plastic fibers has low specific gravity of 1.12 when compared to cement that has specific gravity of 3.15 and aggregate 2.65. Not only has that, the plastic fibers taken up the water resulting in the need for more quantity of water to improve the density.

3.2. Hardened concrete properties

The results of hardened concrete tests are presented in Table 5, which included the 7, 14 and 28days of both compressive strength and flexural strength tests. As observed from results and showed in Fig. 9, the addition of WPF leads to increase in compressive strength of all mixes compared with a reference mix for all ages of test. The SCC developed compressive strengths ranging from 46 MPa to 56Mpa, from 51 MPa to 68 MPa, and from 53 MPa to 76Mpa, at 7, 14 and 28 days, respectively.

Among all WPF mixes, the concrete specimens incorporated WPF with V_f=2% achieved the lowest compressive strength for all test ages. The maximum increment in compressive strength at 7 d age according to reference mix was equal to 21.7% for F1.0 mix (V_f=1%), whereas the value at 14 d of curing was 33.33%for F1.25 mix (V_f=1.25%), and at 28 days curing was equal to 43.4% for F1.5 mix (V_f=1.5%). As and when micro cracks developed in the matrix, the fiber in the vicinity of such micro cracks tries to arrest these cracks and prevent further propagation. Hence the cracks that are appearing inside the matrix have to take a meandering path, resulting in the demand for more energy for future propagation, which in turn increases the ultimate load [23].

It can be clearly noticed that from Fig. 10 the flexural strength of all reinforced fiber concrete mixtures is higher than that of the control concrete mix. The results of the flexural tensile strength tests clearly showed the benefit of WPF fibers. The trends illustrated a definite increase in tensile capacity attributed to higher fiber concentrations. The tested prisms for plain concrete failed suddenly and split into two separate parts, while the prisms with fibers are cracked at failure without separation. All fibrous mixes except mix F2.0 (V_f=2%) demonstrated higher flexural tensile strength relative to plain mix at all curing ages. The percent of increase in flexural tensile strength was found to be increased

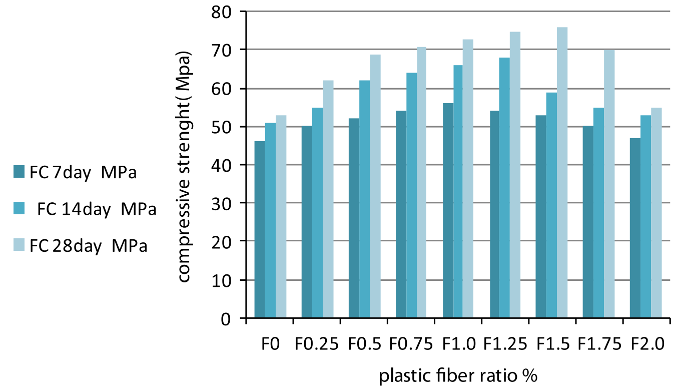

Fig. 9. Variation in compressive strength with plastic fibers ratio of all SCCs mixes.

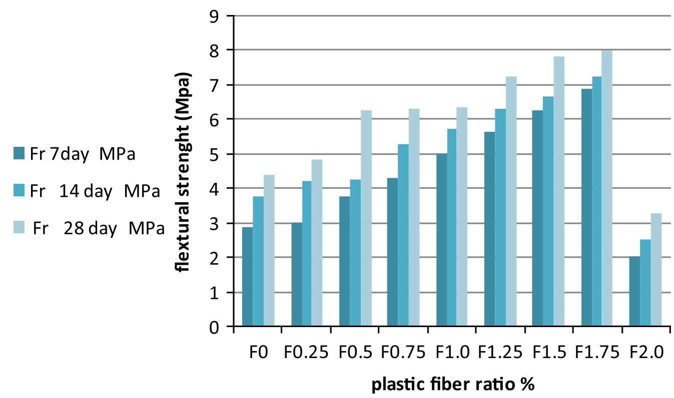

Fig. 10. Variation in flexural strength with plastic fibers ratio of all SCCs mixes.

with the increase in WPF content up to (V_f=1.75%). With an increase in fiber content, the fibers become more densely spaced, and may hinder growth of micro cracks within the brittle matrix and increase the flexural tensile strength of the fiber reinforced concrete [50]. The maximum increasing values in flexural strength according to Reference mix at 7, 14 and 28 days age of curing were 141.4%, 93.3% and 82.2% respectively for F1.75 mix (V_f=1.75%). However, at highest value of WPF content (V_f=2%), a reduction in ultimate flexural strength has been found. This may be due to the insufficient matrix around the fibers for transfer of stress from concrete to fibers through bond [24]. Moreover plastics are having low bonding properties so that causing a decrease in flexural strength with higher content of PET. As the plastic content increases, more free water around the particles weakens the plastic-paste interface resulting in a less dense zone with large voids and a relatively poor adhesion [51]. It is the reason why the flexural strength is apparently reduced if the fiber fraction is bigger than 1.75%.

A fractured surface is shown in Fig. 11a and b where parts of the plastic particles are marked with small circles. The coarse

Table 5
Hardened properties.

Mix ID	F_C 7 d MPa	F_C 14 d MPa	F_C 28 d MPa	F_r 7 d MPa	F_r 14 d MPa	F_r 28 d MPa
F0	46	51	53	2.85	3.75	4.39
F0.25	50	55	62	3.0	4.2	4.85
F0.5	52	62	69	3.75	4.25	6.25
F0.75	54	64	71	4.28	5.29	6.30
F1.0	56	66	73	5.0	5.75	6.38
F1.25	54	68	75	5.66	6.33	7.25
F1.5	53	59	76	6.25	6.69	7.85
F1.75	50	55	70	6.88	7.25	8
F2.0	47	53	55	2	2.5	3.25

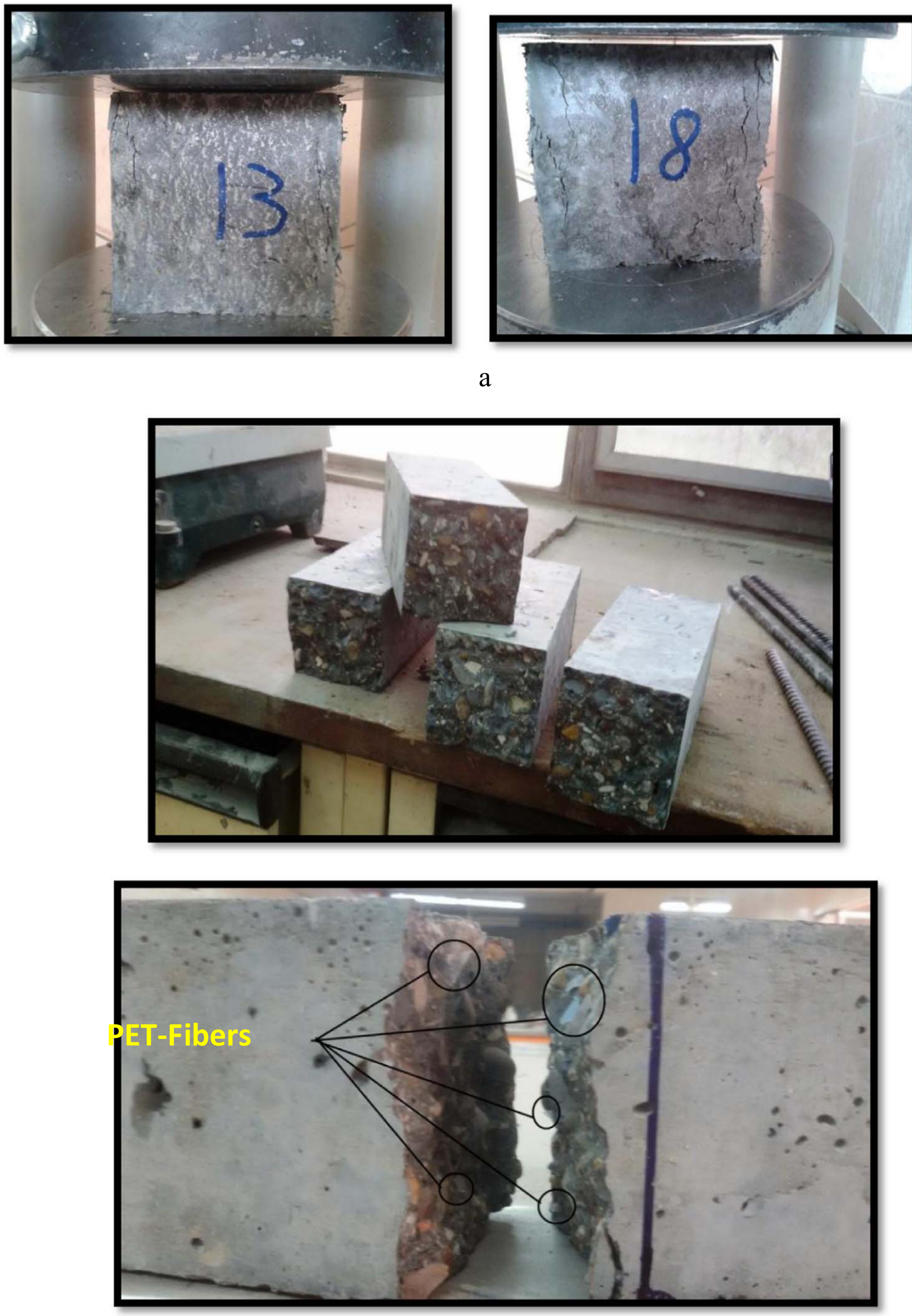

Fig. 11. a- Failure mode after compressive test. b-Failure mode after Flexural strength test.

aggregate and plastic particles distribute uniformly in the section. Moreover, all the coarse aggregates are fractured finally. The fracture surface of concrete cubes and prismatic showed that most of plastic wastes are pulled out from the specimens.

3.3. *Ultrasonic Pulse Velocity Test (UPV)*

The results of UPV test are presented in Table 6. It is seen that all UPV values of fiber concrete as well as reference concrete specimens are in the range of 3.4–5.2 km/s, which indicates the quality of concrete falls in the "good" scale as per quality assessment of IS: 13,311 [52]. It was noted that the inclusion of PET fibers

Table 6
Test results of UPV.

Mix ID	***Age days***	**UPV** Km/s
F0	28	3.60
F0.25	28	5.20
F0.5	28	4.80
F0.75	28	4.50
F1.0	28	4.13
F1.25	28	3.67
F1.5	28	3.40
F1.75	28	4.64
F2.0	28	4.06

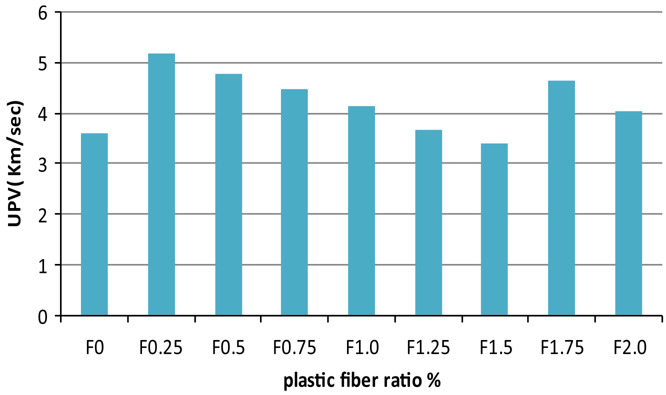

Fig. 12. Variation in pulse velocity with plastic fibers ratio of all SCCs mixes.

led to increase on the UPV for all mixes containing this kind of fibers comparing with reference mix. For the mixes containing PET fibers UPV values decreased with an increasing in PET content up to V_f=1.5% due to their lower specific gravity. The relationship between the pulse velocities of the specimens at 28 days reinforced with plastic fibers and volume fraction of these fibers is shown in Fig. 12, but, this figure appears to be really inadequate to explain this relationship. Furthermore, when correlating this property with the corresponding compressive strength, the regression will not be linear because of the fiber concrete's greater capability of withstanding tensile forces. This renders the UPV test somewhat ineffective as a non-destructive test to estimate the compressive strength of concrete as according to previous studies [53].

4. Conclusions

Based on the findings presented above, the main concluding remarks can be explained as follows:

- The slump flow diameters ranging from 650 to 780 mm were obtained for the self-compacting concretes. The reference mixture was in the SF1 class while the self-compacting rubberized concretes with WPF were in the SF3 class according to EFNARC. Although the increasing in WPF content which led to reduce the slump flow diameters of concretes, the results were acceptable for many normal application of self-compacting concrete.
- The addition of WPF leads to increaseinboth T_{50} slump flow and V-funnel flow times. All the mixture can be categorized as VS2/VF2 viscosity class, due to the fact that using the WPF in production of self-compacting concrete increases the T_{50} slump flow and V-funnel flow times. The produced concretes determine the self-compacting concrete requirements according to EFNARC.
- The L-box height ratio was also affected by the content of WPF use, since increasing the WPF content causes systematic decrease in the L-box height ratio. However, the seventh mixtures had L-box height ratio values more than 0.8 which is the lowest limit determined by EFNARC, while the F1.75 mix and F2.0 are not satisfying the requirements of SCC.
- As waste plastic fibers WPF were added, wet density values of all mixtures generally became lower. The reason for this reduction attributed to the fact that the plastic fibers has low specific gravity.
- The compressive strength results indicate that the utilization of WPF in manufactured self-compacting concrete led to systematical increasing of the compressive strength. Among all WPF mixes, the concrete specimens incorporated WPF with (V_f=2%) achieved the lowest compressive strength for all test ages. The compressive strength of self-compacting concrete with WPF having more than 40 MPa could be produced easily.
- flexural strength of all reinforced fiber concrete mixtures is higher than thatof the control concrete mix. The results of the flexural strength tests clearly showed the benefit of WPF fiber**s.**
- The UPV values ranging from 3.40 km/s to 5.20 km/s were achieved in this study. The lowest UPV result was obtained from control mixture while the highestUPV result was obtained from manufacturing F0.25 mix (V_f=0.25%).

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